# GUIDELINES:

## Air Quality Surveillance Networks

U. S. ENVIRONMENTAL PROTECTION AGENCY

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ENVIRONMENTAL PROTECTION AGENCY
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## INTRODUCTION

Air Quality Control Regions have been designated for the entire United States. For these regions an inherent part of the control effort is the development of an air quality surveillance program. In some areas, existing networks will be modified or expanded; in others, new surveillance programs must be developed. Although past efforts were concerned primarily with sulfur dioxide and particulates, regional surveillance programs will need to be expanded to include other pollutants such as carbon monoxide, nitrogen dioxide, non-methane hydrocarbons, and oxidants.

The guidelines presented here will assist State and local agencies in setting up air quality surveillance programs. The development of an air quality surveillance program includes determining the number and location of sampling sites, selecting appropriate instrumentation, and establishing a data information system. Experience and technical judgment are essential for determining the number and location of sampling sites because adequate mathematical models or other methods have not been formulated.

The development and implementation of the system must by necessity involve a trade-off between what is considered desirable from a strictly technical point of view and what is feasible with the available resources. An ideal network will in almost all instances require more resources than are available. In light of this, the design discussed in this paper centers on a minimally adequate surveillance network - a network less than ideal, yet capable of meeting the major surveillance requirements. The basic difference between a minimally adequate surveillance network and the ideal is that the minimal network has fewer and perhaps less sophisticated instruments. Designers of the network should attempt to maximize the effectiveness of the minimally adequate network through careful selection of sampling sites, scheduling of variable sampling frequencies, and possible use of mechanical (integrated) as well as automatic (continuous) samplers.

Because of limited resources, some air quality control regions may be required to build up to an adequate surveillance network over a period of time. The surveillance network established under conditions of limited resources would be the starting point upon which a future network could be built. In such cases a schedule for expansion should be compiled early to allow for systematic buildup and to guide the allocation of resources.

This report deals with four major aspects of regional surveillance: (1) objectives of surveillance, (2) design of a minimally adequate surveillance network, (3) laboratory requirements, and (4) data acquisition and analysis.

## OBJECTIVES OF REGIONAL SURVEILLANCE

Regional air quality surveillance networks are inherent parts of the implementation plans currently required for sulfur oxides, particulates, carbon monoxide, hydrocarbons, oxidants, and nitrogen oxides. Generally, surveillance networks for all of these pollutants must be established in a region. Although each pollutant requires separate analysis, the collection of samples can be generalized into two groups: (1) a particulate network, which is the source of information for suspended particulates, and (2) a gas network, which consists of sampling devices for CO, $SO_2$, NO, $NO_2$, nonmethane and total hydrocarbons, and oxidants. The need for surveillance for each pollutant will depend on the amount of pollution present within the region. For example, whereas one region may require extensive surveillance, of, say, oxidants, the relative absence of this pollutant in another region may preclude such an extensive surveillance effort.

Air quality surveillance within a region must provide information to be used as a basis for the following actions:

1. To judge compliance with and/or progress made toward meeting ambient air quality standards.
2. To activate emergency control procedures to prevent air pollution episodes.
3. To observe pollution trends throughout the region including the nonurban areas. (Information on the nonurban areas is needed to evaluate whether air quality in the cleaner portions of a region is deteriorating significantly and to gain knowledge about background levels.)
4. To provide a data base for application in evaluation of effects; urban, land use, and transportation planning; development and evaluation of abatement strategies; and development and validation of diffusion models.

## DESIGN OF AN AIR QUALITY SURVEILLANCE NETWORK

An air quality surveillance program is composed of three distinct but interrelated elements: sampling networks, laboratory support, and data acquisition and analysis. With automatic (continuous) instrumentation the need for routine laboratory support is greatly reduced, but a problem of data transmission, validation, and reduction is introduced. Network design entails such considerations as the number and type of stations needed, their locations, frequency of sampling, and duration of collection period for each sample. The kind of network specified for a given region will also determine the requirements for laboratory sampling and analysis procedures, laboratory support, and data acquisition and analysis systems.

The two general types of networks required for regional air quality surveillance are (1) a particulate network and (2) a gaseous network.

The particulate network should be composed primarily of high-volume samplers (Hi-Vols) and tape samplers. The Hi-Vols are used to collect total suspended particulates (TSP), which may be subsequently fractionated into trace elements and compounds. Tape samplers provide an indication of suspended particulate loading over periods of less than 24 hours, primarily for use during air pollution episodes. The total particulate network design, i.e., number and location of Hi-Vol stations, will most likely be determined by the sampling requirements for TSP. The extent to which the Hi-Vol samples are analyzed for a particular constituent depends upon local circumstances. It is important to note that practical field techniques are being perfected for measuring the respirable size fractions of TSP.

The gas network may be composed of a mixture of mechanized and automated sampling devices. For some pollutants, such as sulfur dioxide, nitrogen oxides, and oxidants, both types of samplers may be used. Where pollution levels are substantial, the urban core network will typically be composed of automatic sampling stations, with the mechanical stations being relegated to areas of lower concentrations between widely spaced automated stations.

## Information Required for Network Design

Knowledge of the existing pollution levels and patterns within the region is essential in network design. The areas of highest pollution levels must be defined, together with geographical and temporal variations in the ambient levels. Isopleth maps of ambient concentrations derived from past sampling efforts and/or from diffusion modeling are the best tools for determining the number of stations needed and for suggesting the station locations. Additionally, information on meteorology, topography, population distribution, present and projected land uses, and pollution sources is extremely helpful in network design. In fact, where isopleth maps are not available, such information, which can usually be obtained readily from organizations such as the Bureau of Census, National Weather Service, and local planning agencies, provides the basis for initial design.

In the absence of isopleth maps, information on emission densities and/or land use can be used together with wind-rose data to pinpoint areas of expected higher concentrations. Topographical maps provide additional information on wind flow and pollution dispersion characteristics. Maps of population distribution are essential in locating key stations for monitoring during episodes.

In some cases adequate information for network design will not be available; the resulting networks will need to be modified as more information and experience are obtained.

## Network Size

The number of sampling stations required depends primarily on the existing pollution levels, their variability, and the size of the region. The number of sampling stations must be adequate to allow definition of the area or areas where ambient concentrations may be expected to exceed air quality standards. Information on air quality in other areas, including the nonurban portions of the region, should also be gathered.

A first approximation of the number of stations required in a region may be obtained from Figure 1, in which the number of stations is shown as a function of total population. The curves in Figure 1 show a spread suggesting a minimum and a maximum number of stations for each population class depending on the extent and degree of pollution. For example, a region of 1 million inhabitants with a severe $SO_2$ problem may require up to 25 samplers, whereas one of similar size with a minimal $SO_2$ problem would require only 10 samplers. Although the curves should provide good estimates for application to population- or motor-vehicle-related pollutants such as CO, HC, $NO_x$, and oxidant (ozone), they do not necessarily apply as well to $SO_2$ and particulate matter. For the latter pollutants, industrial complexity and fuel-use patterns in the region strongly influence the pollution levels and thus affect network size regardless of the population.

Surveillance of $SO_2$ and $NO_x$ requires an additional decision concerning the mixture of mechanical and automatic samplers. A first approximation can again be obtained from Figure 1. The curve for mechanical samplers provides the estimate for the total number of $SO_2$ samplers needed. The difference between the estimates for mechanical and automatic samplers is the actual number of mechanical samplers required.

Figure 1 is intended only as a general guide to network size. The curves are based on a qualitative evaluation of cities of different population classes in terms of their existing networks, pollution patterns, and geographic distribution of sources. The relationship between population and network size was derived from such investigations combined with experience and knowledge. In general, population is a good index to network size and such data are easily obtainable. There are, however, certain situations, such as the relative absence of $SO_2$ pollution in the western portion of the United States, in which these curves are not applicable. In these cases, more-specific information on sources and emissions is essential before network size can be determined.

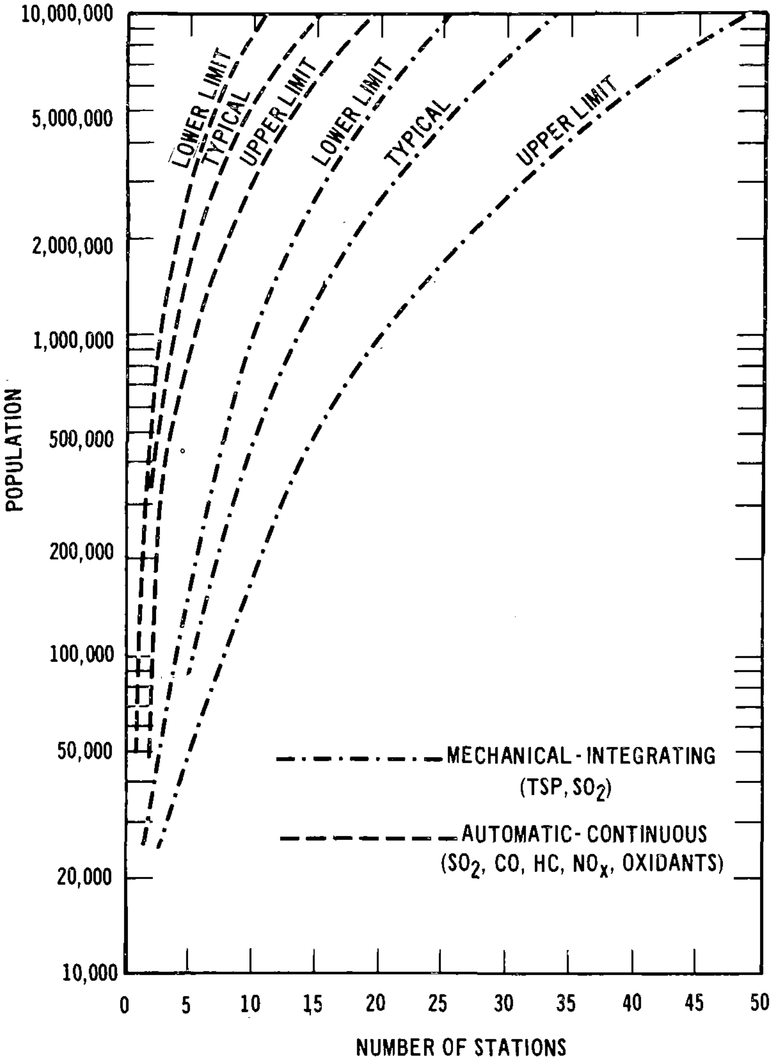


Figure 1. Region population versus number of stations.

Another approach for approximating the number of stations required within a region incorporates information on existing levels of pollution as a function of the area of the region. Where isopleth maps are available, they should be used for estimating network size. At the present time, use of the mathematical approach is limited to the design of surveillance networks for suspended particulates and sulfur dioxide.

The equation for estimating network size relates the number of stations to the degree of pollution and the land area of the region. It is based on the fact that more stations are needed in zones where ambient air pollutant concentrations may be expected to exceed the ambient air quality standards and that the concentrations influence the number of stations. The equation considers distinct areas: the area, X, where the pollution levels are higher than the ambient air quality standard; the area, Y, where pollution levels are above background but lower than the standard; and the area, Z, where existing concentrations are at background levels. In these calculations all air quality data are expressed in terms of annual averages. The total number of samplers, N, required for the entire region is obtained by summing the estimated numbers of samplers for each of the three subareas.

$$N = N_x + N_y + N_z \tag{1}$$

The subareas are described as follows:

$$N_x = 0.0965 \frac{C_m - C_s}{C_s} X \tag{1a}$$

$$N_y = 0.0096 \frac{C_s - C_b}{C_s} Y \tag{1b}$$

$$N_z = 0.0004 Z \tag{1c}$$

Where:

$C_m$ = Value of maximum isopleth* (with a contour interval of 10), $\mu g/m^3$

*Table 1 provides estimated background values for total suspended particulates and $SO_2$ for use when isopleth information is not available.

Table 1. TSP AND $SO_2$ VALUES FOR NONURBAN BACKGROUND TERM IN EQUATION 1

($\mu g/m^3$)

| | Proximate[a] | Intermediate[b] | Remote[c] |
|---|---|---|---|
| Total suspended particulate | 45 | 40 | 20 |
| Sulfur dioxide | 20 | 10 | 5 |

[a] Proximate values based upon NASN stations in the following states: Connecticut, Delaware, District of Columbia, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, Rhode Island.

[b] Intermediate values for all other states.

[c] Remote values based upon NASN stations in the following states: Colorado, Idaho, Michigan, Minnesota, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Utah, Wisconsin, Wyoming.

$C_s$ = Ambient air quality standard, $\mu g/m^3$

$C_b$ = Value of the minimum isopleth (again with a contour interval of 10), $\mu g/m^3$

X = Area wherein concentrations are higher than ambient air quality standard, $km^2$

Y = Area wherein concentrations are above background but less than ambient standard, $km^2$

Z = Area wherein concentrations are at background levels, $km^2$

Use of these equations requires the division of the region into three zones on the basis of isointensity lines representing the ambient air quality standard and the background value appropriate for the region. The land areas of each zone are determined from the isopleth map, as are the maximum and minimum concentrations in the region. Note once more that concentration values used in the equation are annual averages. The above equations should not be used to estimate the numbers of background stations where regions encompass excessively large unpopulated areas. No more than four or five background stations should be necessary in any region.

The equation for determining number of stations was derived from an in-depth analysis of the relationship between pollution levels and patterns, geometric distribution of sources, meteorology, and land area in the National Capital Interstate Air Quality Control Region. The equation was verified by application to several other cities in the United States with various population and pollutant distributions. As mentioned earlier, it is applicable only to $SO_2$ and TSP networks. The same general approach, with different constants, can be applied to determine the size of networks for the measurement of other pollutants. These constants will be developed when more data become available.

## Station Location

Selecting the locations of stations and samplers involves decisions regarding (1) distribution of samplers within the region and (2) specific site selection for each station. The first decision requires consideration of surveillance objectives, overall pollution patterns, and the needs for governmental jurisdictional coverage. Selection of the particular site is based upon representativeness of the area and other practical aspects such as housing the samplers, electric power, and security from vandalism.

The information required for selecting sampler location is essentially the same as that for determining network size, i.e., isopleth maps, population density maps, source locations. Following are suggested guidelines:

1. The priority area is the zone of highest pollutant concentration within the region. One or more stations are to be located in this area.
2. Close attention should be given to densely populated areas within the region, especially when they are in the vicinity of heavy pollution.
3. For assessing the quality of air entering the region, stations must also be situated on the periphery of the region. Meteorological factors such as frequencies of wind direction are of primary importance in locating these stations.
4. For determining the effects of future development on the environment, sampling should be undertaken in areas of projected growth.

5. A major objective of surveillance is evaluation of the progress made in attaining the desired air quality. For this purpose, sampling stations should be strategically situated to facilitate evaluation of the implemented control tactics.

6. The National Air Surveillance Network (NASN) sampling sites within a region should be included as an integral part of the proposed network. It is expected the appropriate agency will take over and continue to operate this station(s) at the existing site to provide continuity of air quality at a given location.

7. Some information of air quality should be available to represent all portions of the region.

The air quality surveillance network should consist of stations that are situated primarily to document the highest pollution levels in the region, to measure population exposure, to measure the pollution generated by specific classes of sources, and to record the nonurban levels of pollution. Many stations will be capable of meeting more than one of these criteria; e.g., a station located in a densely populated area besides measuring population exposure could also document the changes in pollutant concentrations resulting from new control strategy employed in the area.

Although the sampler locations depend on many factors, some idea of sampler distribution may be obtained from Tables 2 and 3, which show sampler location as a function of network size. Table 2 summarizes distribution of mechanical samplers, such as Hi-Vols; Table 3 shows distribution of automatic samplers. With respect to locations shown in Tables 2 and 3 it will be necessary to consider wind patterns, source locations, and distribution of emissions in selecting approximate locations for these sites. For example, stations in the highly populated area should be so situated that they can accurately assess the pollution impact under different meteorological conditions. Although both types of stations follow the same general pattern, the tendency is for wider distribution of mechanical sampling stations.

It is the intent of these guidelines to suggest that a simple network be developed to measure the concentration of as many pollutants as possible. It is likely that common sites, although not necessarily ideal for each pollutant, may be

Table 2. DISTRIBUTION OF MECHANICAL (INTEGRATED) SAMPLING STATIONS[a]

| Total number of stations | Number of stations in: Center city/ industrial | Residential zones | Nonurban |
|---|---|---|---|
| 1 | 1 | - | - |
| 2 | 1 | 1 | - |
| 3 | 2 | 1 | - |
| 4 | 2 | 2 | - |
| 5 | 2 | 2 | 1 |
| 10 | 5 | 3 | 2 |
| 15 | 8 | 5 | 2 |
| 20 | 12 | 6 | 2 |
| 25 | 14 | 8 | 3 |
| 30 | 17 | 10 | 3 |

[a]Includes Hi-Vol sampler and $SO_2$, $NO_2$, and oxidant (ozone) collecting devices.

Table 3. DISTRIBUTION OF AUTOMATIC (CONTINUOUS) SAMPLING STATIONS[a]

| Total number of stations | Number of stations in: Center city/ industrial | Residential zones | Nonurban[b] |
|---|---|---|---|
| 1 | 1 | - | - |
| 2 | 1 | 1 | - |
| 3 | 2 | 1 | - |
| 4 | 2-3 | 1-2 | - |
| 5 | 3 | 2 | - |
| 6 | 4 | 2 | - |
| 10 | 6 | 4 | - |
| 15 | 10 | 5 | - |

[a]Includes $SO_2$, CO, HC, NO, $NO_2$, and oxidant (ozone).

[b]Where ozone damage has been identified in nonurban areas, surveillance may be necessary.

selected to provide adequate coverage for the pollutants of concern. Each pollutant, however, should be considered individually during the design phase to pinpoint pockets of high pollution that otherwise might be overlooked.

The final task in determining sampler placement is to find a specific location with the proper facilities for operating the sampler. Availability of space and power, accessibility, security, and representativeness of the site determine the precise location.

## Sampling Frequency

The sampling frequencies for mechanical samplers and the averaging times for automatic samplers are dictated by the ambient air quality standards. If, for instance, standards are set in terms of days, hours, or minutes, then the sampling frequencies must be in the same averaging time.

Although standards for TSP and $SO_2$ are prescribed in terms of annual averages and maximum daily concentrations, it is impractical to operate the entire network on a daily basis. Adequate coverage may be maintained with intermittent sampling at frequencies calculated statistically for desired levels of precision. Suggested sampling frequencies are presented in Table 4, which relates frequency of sampling to the degree of pollution, ranging from every third day sampling in the highly polluted zones to once every sixth day in the nonurban zones. Twenty-four-hour sampling should be from midnight to midnight to represent calendar days and to permit direct utilization of the sampling data with standard daily meteorological summaries.

## Sampling Site Characteristics

The preceding sections gave guidelines for the general distribution of sampling stations within a region. The selection of a particular site for a single sampler or a complex station is equally important. It is essential that the sampler be situated to yield data representative of the location without undue influence from the immediate surroundings. No definitive information is available concerning how air quality measurements are affected by the nearness of buildings, height from ground, and the like. There are, however, general guidelines that should be considered in site selection:

1. Uniformity in height above ground level is desirable for the entire network within the region. Some exceptions may include canyons, high-rise apartments, and sites for special-purpose samplers.
2. Constraints to airflow from any direction should be avoided by placing inlet probes at least 3 meters from

Table 4. FREQUENCY OF SAMPLING BY INSTRUMENT TYPE WITHIN AREA

| | Type of instrument | Frequency of sampling: Areas above standard: Continuous | Areas above standard: Every third day | Areas above standard: Every sixth day | Other urban areas: Continuous | Other urban areas: Every third day | Other urban areas: Every sixth day | Nonurban areas: Every sixth day |
|---|---|---|---|---|---|---|---|---|
| Particulates | | | | | | | | |
| Total suspended particulate[a] | M[b] | | M | M | | M | M | M |
| Polycyclic organic matter | M | | M | M | | M | M | |
| Gases | | | | | | | | |
| $SO_2$ | M/A[c] | A | | M | | M | M | M |
| CO | A | A | | | A | | | |
| Non-methane HC | A | A | | | A | | | |
| $NO_2$ | M/A | A | M | M | A | | M | |
| $NO_x$ ($NO + NO_2$) | M/A | A | M | M | A | | | |
| Oxidant ($O_3$) | M/A | A | M | | A | | | |

[a]Spot-tape samplers provide an indication of TSP on a less than 24-hour basis.

[b]M represents mechanical samplers.

[c]A represents automatic samplers.

buildings or other obstructions. Inlet probes should be placed to avoid influence of convection currents.

3. The surrounding area should be free from stacks, chimneys, or other local emission points.

4. An elevation of 3 to 6 meters is suggested as the most suitable for representative sampling, especially in residential areas. Placement above 3 meters prevents most reintrainment of particulates, as well as the direct influence of automobile exhaust.

## Methodology and Instrumentation

Information on types of instrumentation, its use, specificity, and associated costs is summarized in Table 5.

Development of instruments and techniques for sampling and analysis is progressing rapidly. Numerous instruments and techniques are now available for sampling and analysis. Standard methods are under development by the Air Pollution Control Office and the Intersociety Committee.* Until such standard methods are prescribed, the preferred methods of sampling and analyses are those for which a large body of data is available. Recommended reference methods are described in the Federal Register (April 30, 1971) with the National Ambient Air Quality Standards for $SO_2$, CO, $NO_x$, oxidant, hydrocarbons, and particulate matter. Acceptable methods for sampling and analysis are those that have been compared with standard or reference methods and have proved comparable in collection efficiency and in specificity. Whatever method is chosen, caution should be exercised to purchase instruments that have been thoroughly field tested.

Continuous production of valid data requires that instruments be properly maintained. This includes calibration prior to installation and on a routine basis thereafter. Most modern continuous instruments provide for automatic dynamic

*Member societies are: Air Pollution Control Association (APCA), American Council of Governmental Industrial Hygienists (ACGIH), American Industrial Hygiene Association (AIHA), American Public Health Association (APHA), American Society of Mechanical Engineers (ASME), American Society for Testing and Materials (ASTM), and Association of Official Analytical Chemists (AOAC).

Table 5. CLASSIFICATION OF AIR POLLUTION SAMPLING TECHNIQUES

| Type | Use | Specificity | Common averaging time | Relative cost[a] | Required training of personnel[b] | Remarks |
|---|---|---|---|---|---|---|
| Mechanical | | | | | | |
| Hi-Vol | Integrated quantification | Total suspended particulate and multiple specific pollutants | 24 hours | Moderate | Moderate | Detailed chemical analysis of Hi-Vol and gas samples require sophisticated laboratory trained chemists, and is costly. |
| Gas sampler | Integrated quantification of gas | $SO_2$, $NO_2$ | 24 hours | Moderate | High | |
| Spot tape sampler | Relative soiling index | Unknown | 2 hours | Low | Low | Provides only a rough, relative index of particulate soiling. |
| Automatic | | | | | | |
| Gas | Continuous analysis of gaseous pollutants | Single gas or group of related gases | Continuous sample integration usually 1-15 months | Moderate to high | Moderate to high | Continuous measurements allow use of any desired averaging time by computation. Accuracy is generally much better than other methods. Calibration is simplified. Data is available instantaneously. |
| Particulate sorting (automatic tape) | Continuous analysis of soiling rate | Unknown | (Same as above) | Moderate | Moderate | |

[a] Low refers to \$0-\$500; Moderate refers to \$500-\$2000; and High refers to above \$2000.

[b] Low requires common maintenance; Moderate requires a technician; and High requires an experienced technician or professional with professional support staff.

calibration at least daily. Dynamic calibration either by permeation devices or gaseous mixtures is preferred. Static calibration is subject to stoichiometric factors and does not take into account collection efficiency of the continuous sampling instrument.

## LABORATORY OPERATIONS

Support of the surveillance networks will require laboratory operations of varying levels of complexity. The requirements for laboratory support, in terms of size and complexity, will be dictated by the pollutants of interest in the region, size of the networks, and the degree of pollution. The laboratory should be equipped for analyses of samples for at least TSP, $SO_2$, $NO_2$, and oxidant and should provide for calibration of all collecting and measuring devices and preparation of reagents.

Some regions will require laboratory capability for analyses of trace elements, fluorides, and other pollutants. In large laboratories with requirements for a large number of analyses, automated laboratory procedures should be considered.

## DATA ACQUISITION AND ANALYSIS

The design of a network must be accompanied by design of a system of data acquisition and analysis that considers the flow of data and their use.

To insure uniformity of data across the country and also to assist State and local agencies in data handling and analyses, the Environmental Protection Agency is expanding the National Aerometric Data Information Service (NADIS). This service encompasses the operation of a National Aerometric Data Bank, the systematic gathering of all aerometric data, and the provision for data dissemination in the form of summaries and special analyses. State and local agencies will routinely submit all air quality data collected to the National Aerometric Data Bank quarterly. All data should be expressed in the SAROAD format. A SAROAD Users Manual gives detailed instructions for coding data in the SAROAD format.